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Regeneration in a tolerant hardwood stand managed under single-tree selection

G. LaRocque

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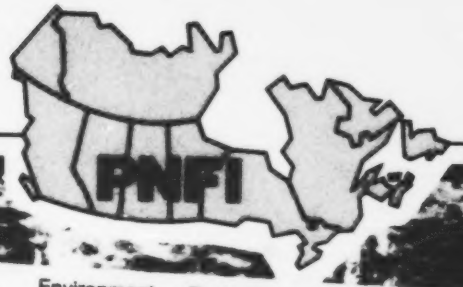
Petawawa National Forestry Institute



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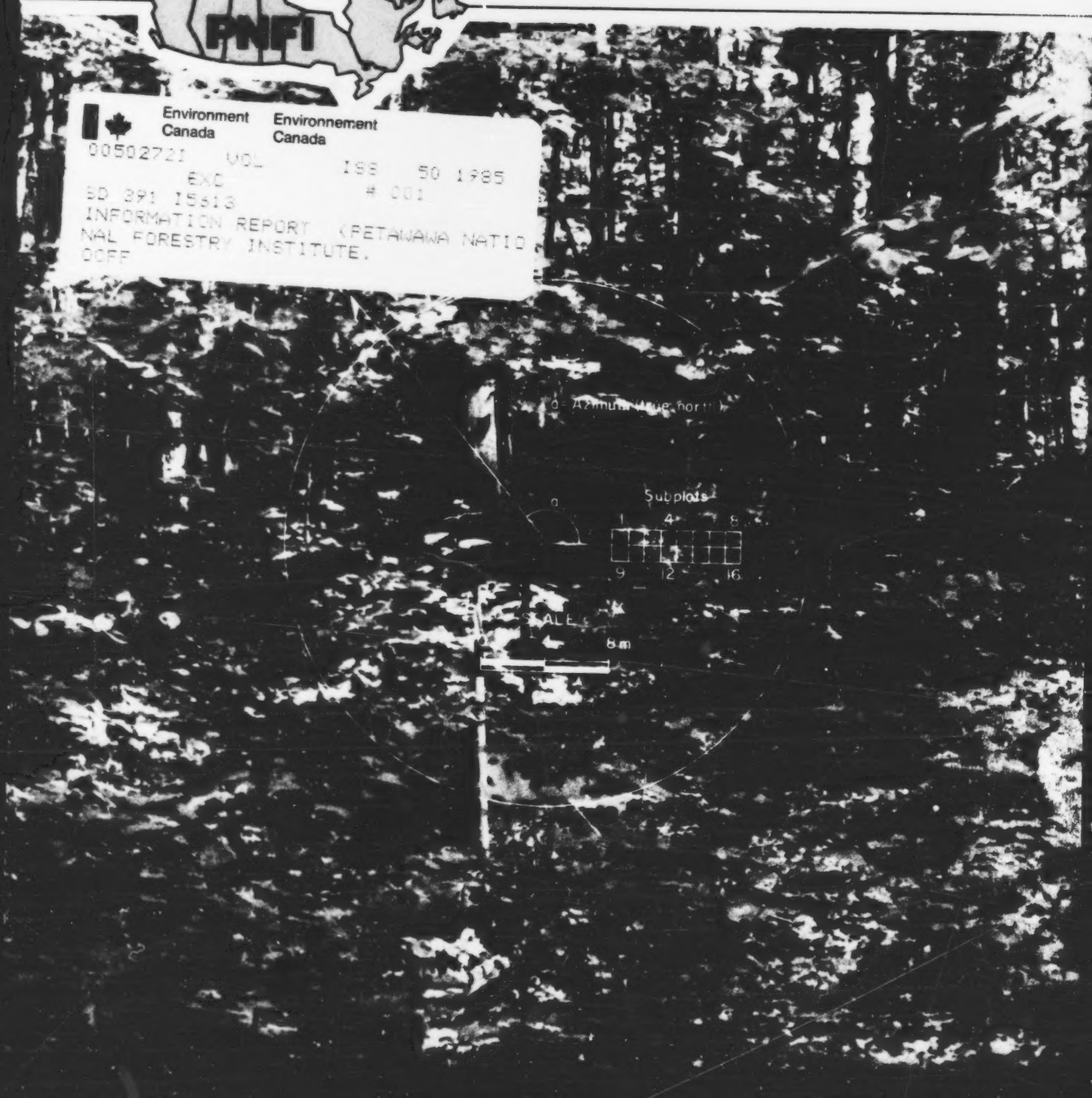

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PETAWAWA NATIONAL FORESTRY INSTITUTE

The Petawawa National Forestry Institute (PNFI) was formed on April 1, 1979, as the result of an amalgamation of the Petawawa Forest Experiment Station with the Ottawa-based Forest Management and Forest Fire Research Institutes. The Forestry Statistics and Systems Branch was established at PNFI in 1980.

In common with the rest of the Canadian Forestry Service, the Petawawa National Forestry Institute has as its objective the promotion of better management and wiser use of Canada's forest resource to the economic and social benefit of all Canadians. Because it is a national institute, particular emphasis is placed on problems that transcend regional boundaries or that require special expertise and expensive equipment that cannot be duplicated in CFS regional establishments. Such research is often performed in close cooperation with staff of the regional centres or provincial forest services.

Research at the Institute is in two main areas:

FIRE RESEARCH AND REMOTE SENSING. Every year in Canada large areas of productive forest are destroyed by fire. Research concentrates on studies of forest fire behaviour, the development of new methods of fire control, the evaluation of fire-fighting equipment and retardants, and the development of computerized fire management systems that are rapidly finding applications with fire-fighting agencies across the country. The environmental and economic impact of forest fires and the use of fire as a silvicultural tool for intensive forest management are also studied.

In remote sensing, investigations are made into the application of modern satellite and airborne remote sensing systems to forestry problems. In this respect, the ARIES digital image analysis system is proving invaluable.

INTENSIVE FOREST MANAGEMENT. As Canada moves into more intensive management of its forest to meet expected increases in demand for this vital resource, the role of this program will become increasingly important. An extensive reforestation program will require a steady supply of high-quality seed of the desired species. Improved growing stock, obtained through tree breeding and forest genetics research, is highly desirable. Increased emphasis is being placed on using the entire above-ground portion of the tree (biomass), but the effect on the environment of this and other forms of intensive management has to be carefully monitored. Biotechnological methods of improving yield while maintaining site productivity are being investigated.

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The operations of PNFI also include THE FORESTRY STATISTICS AND SYSTEMS BRANCH (FSSB) which is responsible for the acquisition and publication of national information on the forests of Canada. Through the Canadian Forest Inventory Committee, which is comprised of provincial and federal forestry officials, the FSSB works in close cooperation with provincial forest agencies to improve and standardize the information available on Canada's forest resources.

Through the FORSTATS program, which involves all regional establishments of the Canadian Forestry Service, the FSSB coordinates the acquisition and publication within the CFS of national statistics on the forest of Canada.

Every five years, the FSSB publishes Canada's Forest Inventory; the official report on the location, extent, species, and condition of the forest resource. In addition, the FSSB is working closely with the provinces to expand the information available on changes to the forest from fire, harvesting, insects and disease, and from forest management activities. This information is essential to the development of sound policies for the improved management of this important and renewable natural resource.

REGENERATION IN A TOLERANT HARDWOOD STAND MANAGED UNDER SINGLE-TREE SELECTION

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Abstract

A regeneration survey was made in a tolerant hardwood stand managed by single-tree selection. Regeneration was assessed to determine whether different treatments within the single tree selection method (residual volume: 140 and 210 m^3/ha; maximum diameter: 40 and 50 cm; cutting cycle: 5 and 10 years) have an effect on seedling density and distribution. Analysis showed that interactions of treatments are more important than each individually. It was found that the highest number of seedlings in the established group can be obtained with the following combination of treatments: residual volume of 140 m^3/ha, maximum diameter of 40 cm, and cutting cycle of 5 years. Furthermore, the distribution of seedlings was found to be influenced only by the residual volume treatment, and best percentages were obtained with 140 m^3/ha. The regeneration is composed mainly of sugar maple (Acer saccharum Marsh.). Beech (Fagus grandifolia Ehrh.), red maple (Acer rubrum L.), and basswood (Tilia americana L.) are found at lower densities. Ten other species were found, but they were sparsely distributed.

Résumé

Un inventaire de régénération a été effectué dans une forêt feuillue tolérante aménagée selon la coupe sélective. Le but était d'évaluer la régénération et de déterminer si différentes intensités de traitement de la coupe sélective (volume résiduel: 140 et 210 m^3/ha; diamètre maximum: 40 et 50 cm; rotation: 5 et 10 ans) ont un impact sur la densité des semis. Les analyses ont montré que les interactions des traitements sont plus importantes que leurs effets seuls. Il a été trouvé que le plus grand nombre de semis dans le groupe établi peut être obtenu à partir de la combinaison suivante de traitements: volume résiduel de 140 m^3/ha, diamètre maximum de 40 cm et rotation de 5 ans. De plus, la distribution des semis est influencée seulement par le volume résiduel et les meilleurs pourcentages ont été obtenus avec 140 m^3/ha. La régénération est composée principalement d'érable à sucre (Acer saccharum Marsh.). Le hêtre (Fagus grandifolia Ehrh.), l'érable rouge (Acer rubrum L.), et le tilleul (Tilia americana L.) ont de bonnes densités, mais moins que l'érable à sucre. Dix autres espèces ont été trouvées, mais en moins grande abondance.

REGENERATION IN A TOLERANT HARDWOOD STAND MANAGED UNDER SINGLE TREE SELECTION

INTRODUCTION

A sound knowledge of forest regeneration is essential for effective forest management because the regeneration phase will determine to a large extent the nature of subsequent forest composition. According to Barret et al. (1962), practices that alter stand density will cause changes in soil temperature, soil moisture, and air temperature within the stand. These modifications may, in turn, affect species composition. Some studies showed that a partial cut may increase species diversity (McClenahen and Hutnik 1979, Curtis and Rushmore 1958, Godman and Tubbs 1973, Hett and Loucks 1971, Hough 1937, 1953, Metzger and Tubbs 1971, Richards and Farnsworth 1971). Barden (1979) believes that, although shade-intolerant and mid-tolerant species can succeed immediately after a partial cut, they will not survive many years.

The purpose of this study was to assess seedling-size regeneration under a single-tree selection system in a shade-tolerant (hereinafter termed "tolerant") hardwood forest, and to evaluate whether different treatments have affected species composition and density.

MATERIALS AND METHODS

Location and nature of stands

The study was conducted in a 24.3-ha tract of tolerant hardwoods at the Petawawa National Forestry Institute (Figure 1). The area is located within the Middle Ottawa Forest Section (L.4c) of the Great Lakes-St. Lawrence Forest Region (Rowe 1972). The soil is a brown podzolic loamy sand derived from glacial till. The soil moisture regime is mostly fresh, according to Hills' (1952) terminology, but locally it is moist or very moist (Berry 1978). The mean daily temperature is 4.3°C and total precipitation is 821.7 mm (Canadian Climate Program 1982).

Table 1 lists species that occur in the study area. Sugar maple and American beech represent about 40% of the total number of stems measuring more than 10 cm dbh, and yellow birch, basswood, and ironwood represent about 25%.

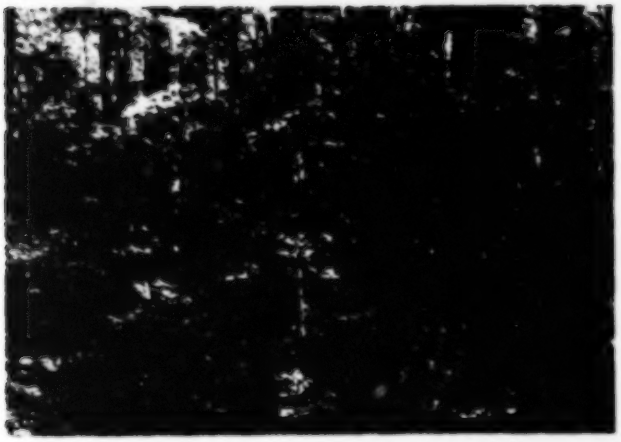
Study history

Research has been conducted in this study area since 1956 by Berry (1963, 1981). His overall purpose has been to test growth response under the single tree selection method with three treatments, each at two levels: (1) residual volume after cut (140 and 210 m^3/ha), (2) maximum diameter limit (40 and 50 cm dbh) and, (3) cutting cycle (5 and 10 years). He also attempted to maintain a diameter distribution that would resemble an inverse J-shaped curve. One of eight different treatment combinations was assigned to each of the eight compartments in the study area (Table 2).

Figure 1. Photos representing stand and regeneration. (a) and (b) show the variability of regeneration. (c) shows a mat of seedlings. As pointed out in the text, the regeneration consists mainly of sugar maple.

a

b



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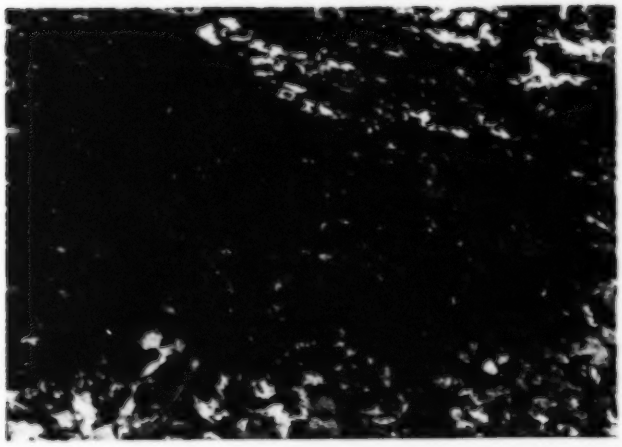

Table 1. Species present in study area

Species	Scientific name
sugar maple	*Acer saccharum* Marsh.
American beech	*Fagus grandifolia* Ehrh.
yellow birch	*Betula alleghaniensis* Britton
basswood	*Tilia americana* L.
ironwood	*Ostrya virginiana* (Mill.) K.
red maple	*Acer rubrum* L.
white birch	*Betula papyrifera* Marsh.
largetooth aspen	*Populus grandidentata* Michx.
black ash	*Fraxinus nigra* Marsh.
white ash	*Fraxinus americana* L.
trembling aspen	*Populus tremuloides* Michx.
white elm	*Ulmus americana* (L.)
red oak	*Quercus rubra* L.
eastern white pine	*Pinus strobus* L.
balsam fir	*Abies balsamea* (L.) Mill.
eastern hemlock	*Tsuga canadensis* (L.) Carr.
white spruce	*Picea glauca* (Moench) Voss
red pine	*Pinus resinosa* Ait.

Table 2. Treatment combinations assigned to each compartment (from Berry 1978)

Compartment	Residual volume (m^3/ha)	Max. diam. (cm)	Cutting cycle (years)	Designation
1	210	50	5	210-50-5
2	210	40	10	210-40-10
3	140	50	5	140-50-5
4	140	40	10	140-40-10
5	140	40	5	140-40-5
6	210	50	10	210-50-10
7	210	40	5	210-40-5
8	140	50	10	140-50-10

Each compartment was sampled by eight permanent plots, some circular and some rectangular, and totalling 0.65 ha. Berry's (1981) inventory procedure consisted first of dbh measurements of every living tree of merchantable size (greater than 8.9 cm dbh). Local volume tables were then utilized to calculate volumes of each tree. Stand tables showing the number of stems by species and diameter class were prepared for the merchantable component. Smaller trees were counted by diameter class for every species, and the number of established seedlings was estimated.

Regeneration survey

A regeneration survey was carried out in August, 1982. Sampling included seedlings less than 1.25 cm dbh. They were divided into seven 0.5-m height classes (Table 3). Counts were made for every class.

In every circular plot the regeneration sample consisted of a rectangular subplot (2 m x 8 m) subdivided in 16 sections. Each subplot was located on a random azimuth bearing and at a random distance from the centre of the circular plot (Figure 2). The total area of the subplots was 128 m^2/ compartment. Within the rectangular plots, subplots were located by randomly selected rectangular coordinates.

Three sections of 1 m^2 were also chosen at random from the 16 sections inside each rectangular 16 m^2 subplot. Seedlings of classes 0, 1, and 2 were counted only in the 1 m^2 subdivisions, whereas seedlings of classes 3 to 6 were counted throughout the 16 m^2 subplots.

Analysis

Data were evaluated using analysis of variance (factorial design) and correlation. Because of the nature of the data (frequency counts) they were subjected to $\sqrt{X + 0.5}$ transformation.

RESULTS AND DISUCSSION

Size class grouping

Table 4 shows the number of seedlings per hectare for each class, treatment combination, and species. One can see from this table the rapid decrease in the numbers of seedlings with increasing size class. Figure 3 gives a better idea of the reduction in seedling numbers: classes 0, 1, and 2 (0.125, 0.50, and 1.00 m in height) are characterized by a drastic decrease in seedling numbers, whereas the larger classes show a more gradual reduction. It was decided to group the 3 smallest classes together as the regeneration group and to consider the larger classes as the established group (Table 5).

Treatment effects on seedling numbers

Regeneration group

Table 6 gives the interaction table of the total number of seedlings (all species combined) for the regeneration group. Although no individual treatment

Table 3. Height classes for regeneration survey

Range (m)	Class no.	Class mid-point (m)
2.75 - 3.24	6	3.00
2.25 - 2.74	5	2.50
1.75 - 2.24	4	2.00
1.25 - 1.74	3	1.50
0.75 - 1.24	2	1.00
0.25 - 0.74	1	0.50
<0.25	0	

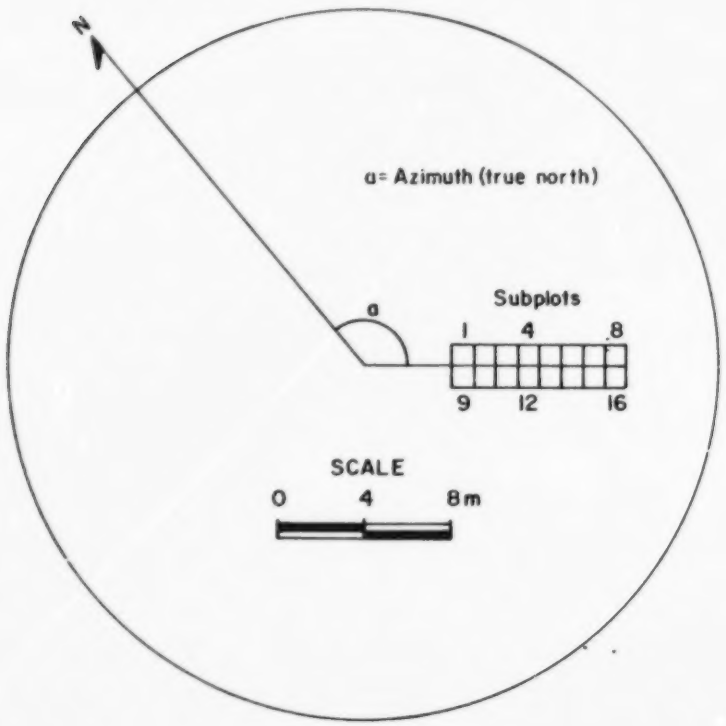

Figure 2. Random selection of azimuth bearing and distance from the centre of each circular plot.

Table 4. Number of seedlings (thousands/ha) by species, compartment, and size class

Class	Treatment combination	Sugar maple	Red maple	Yellow birch	Beech	Basswood	Black ash	White ash	Red oak	White pine	White spruce	Balsam fir	Eastern hemlock	White elm	TOTAL
	210-50-5	97*	2	3	9	2	0	2	0	0.8	0	2	0.8	0	118.6
	210-40-10	91	10	0	7	4	15	0	0.4	1	0	7	0	0	135.4
	140-50-5	93	3	0.4	2	4	45	0	0	0	0	0	0	0.8	148.2
0	140-40-10	154	0.4	0	0.8	0.4	0	15	0	0	0	9	0	0.4	180.0
	140-40-5	109	5	0	2	1	8	3	0	0	0.4	2	0	0	130.4
	210-50-10	90	6	1	8	2	5	7	0	0	0	0.8	0	0	119.8
	210-40-5	54	2	0	3.8	0.4	2	1	0.4	0	0	1	0	0	64.6
	140-50-10	23	7	0	0	0.8	0	0.8	1	0.4	0	6	0	0	39.0
	210-50-5	13	0.4	2	6	0.4	0	0	0	0	0	0.4	2	0	24.2
	210-40-10	3	0	0	1	0.4	0	0	0	0	0	2	0.4	0	6.8
	140-50-5	13	0.4	0.4	0	0	0.4	0	0	0	0	0	0	0	14.2
1	140-40-10	9	0	0	0	0	0	0.8	0	0	0	2	0	0	11.8
	140-40-5	14	0	0	0.8	0.8	3	0	0	0	0	0	0	0	18.6
	210-50-10	35	0.8	0.4	0.8	0	0.4	0	0	0	0	0	0	0	37.4
	210-40-5	8	0	0	0	0.8	0.4	0	0	0	0	3	0	0	12.2
	140-50-10	5	0.8	0	0	0	0	0.8	0.4	0	0	3	0	0	10.0
	210-50-5	3	0	0.8	0.8	0	0	0	0	0	0	0	0.8	0	5.4
	210-40-10	0.8	0	0	0.4	0	0	0	0	0	0	0	0.4	0	1.6
	140-50-5	2	0	0	0.4	0	1	0	0	0	0	0	0	0	3.4
2	140-40-10	3	0	0	0	0.8	0	0.4	0	0	0	0	0	0	4.2
	140-40-5	5	0	0	0.4	0.8	0	0	0	0	0	0	0	0	6.2
	210-50-10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0.4
	210-40-5	0.8	0	0	0	0	0	0	0	0	0	0.4	0	0	1.2
	140-50-10	0.8	0	0	0	0	0	0	0.4	0	0	0	0	0	1.2
	210-50-5	0.5	0	0.1	0.8	0.1	0	0	0	0	0	0	0	0	1.5
	210-40-10	0.2	0	0	0.5	0	0	0	0	0	0	0.2	0	0	0.9
	140-50-5	1	0	0	0.2	0.8	0.1	0	0	0	0	0	0	0.2	2.3
3	140-40-10	1	0	0	0	0.6	0	0.2	0	0	0	0	0	0	1.8
	140-40-5	2	0	0	0.1	0.6	0.2	0	0	0	0	0.1	0	0	3.0
	210-50-10	0.9	0	0	0	0	0.1	0	0	0	0.1	0.1	0	0	1.2
	210-40-5	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.3
	140-50-10	0.1	0.2	0	0.1	0.2	0	0	0	0	0	0.3	0	0	0.9

Table 4 (cont'd)

	210-50-5	0.4	0	0	0.4	0	0	0	0	0	0	0	0	0.8
	210-40-10	0.1	0	0	0.2	0	0	0	0	0	0	0	0	0.1	0.4
	140-50-5	0.3	0.1	0	0.2	0.2	0	0	0	0	0	0	0	0	0.8
4	140-40-10	0.2	0	0	0	0.2	0	0.2	0	0	0	0	0	0	0.6
	140-40-5	1	0	0.1	0	0.3	0.1	0	0	0	0	0	0	0	1.5
	210-50-10	0.3	0	0	0.1	0	0.1	0	0	0	0	0	0	0	0.5
	210-40-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	140-50-10	0.5	0	0	0	0.1	0	0	0.1	0	0	0.1	0	0	0.8
	210-50-5	0.1	0	0	0.1	0	0	0	0	0	0	0	0	0	0.2
	210-40-10	0.2	0	0	0.1	0	0	0	0	0	0	0	0	0	0.3
	140-50-5	0.3	0	0	0.3	0.2	0.1	0	0	0	0	0	0	0	0.9
5	140-40-10	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.3
	140-40-5	0.6	0	0.1	0	0.2	0.4	0	0	0	0	0	0	0	1.3
	210-50-10	0.1	0	0	0.1	0	0	0	0	0	0	0	0	0	0.2
	210-40-5	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0.2
	140-50-10	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0	0.3
	210-50-5	0.1	0	0	0.1	0	0	0	0	0	0	0	0	0	0.2
	210-40-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	140-50-5	0.6	0	0	0.1	0	0.1	0	0	0	0	0	0	0.1	0.9
6	140-40-10	0.3	0	0	0	0	0	0.2	0	0	0	0	0	0	0.5
	140-40-5	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0.2
	210-50-10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.1
	210-40-5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.1
	140-50-10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.1

*The numbers are rounded to the nearest 100 or the nearest 1000 in the case of numbers over 1000.

Figure 3. Number of seedlings/hectare by height classes (averages of the 8 compartments).

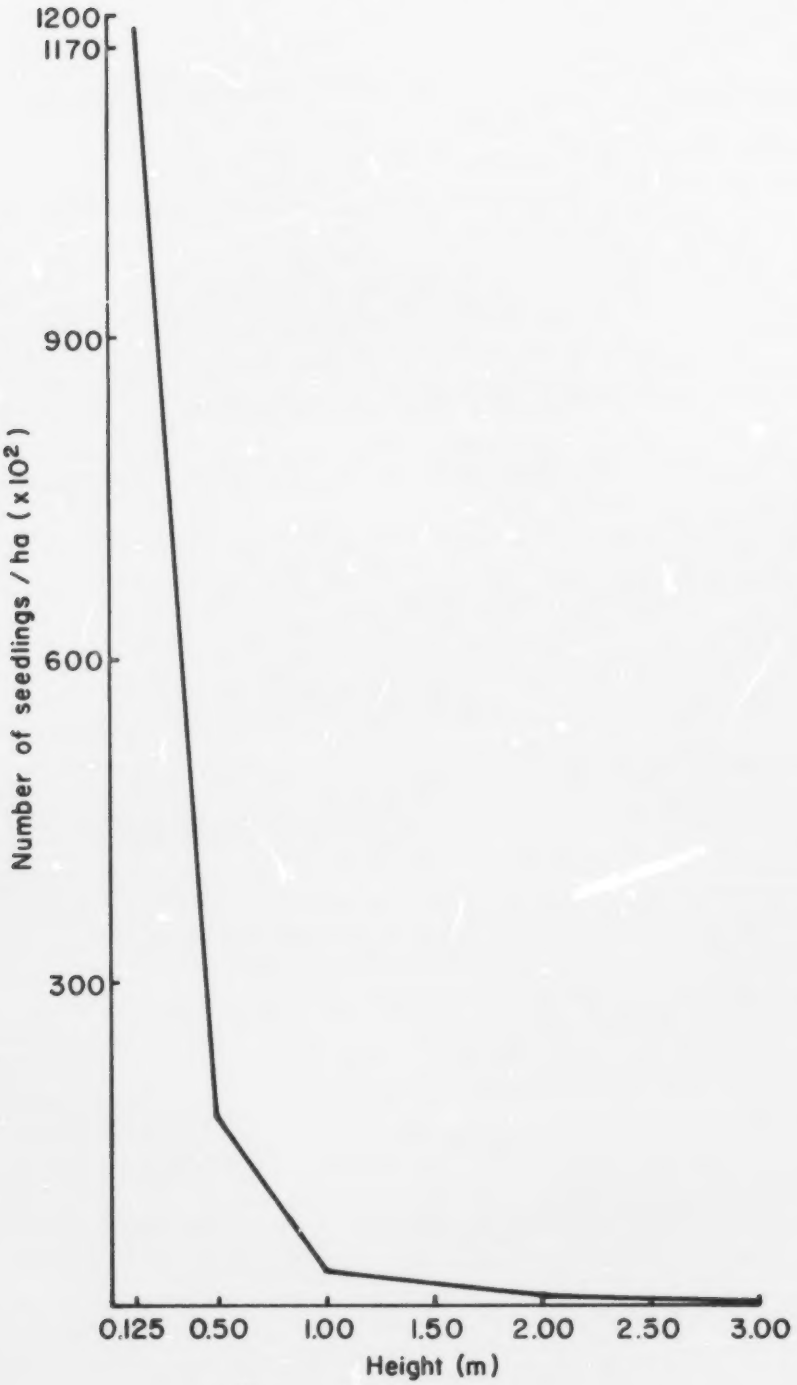

Table 5. Number of seedlings (thousands/ha) by species and compartment grouped in two classes

Class	Treatment combination	Sugar maple	Red maple	Yellow birch	Beech	Basswood	Black ash	White ash	Red oak	White pine	White spruce	Balsam fir	Eastern hemlock	White elm	TOTAL
A*	210-50-5	113	2.4	5.8	15.8	2.4	0	2	0	0.8	0	2.4	3.6	0	148.2
	210-40-10	94.8	10	0	8.4	4.4	15	0	0.4	1	0	9	0.8	0	143.8
	140-50-5	108	3.4	0.8	2.4	4	46	0	0	0	0	0	0	0.8	165.8
	140-40-10	166	0.4	0	0.8	1.2	0	16.2	0	0	0	11	0	0.4	196.0
	140-40-5	128	5	0	3.2	2.6	11	3	0	0	0.4	2	0	0	155.2
	210-50-10	125.4	6.8	1.4	8.8	2	5.4	7	0	0	0	0.8	0	0	157.6
	210-40-5	62.8	2	0	3.8	1.2	2.4	1	0.4	0	0	4.4	0	0	78.0
	140-50-10	28.8	7.8	0	0	0.8	0	1.6	1.8	0.4	0	9	0	0	50.2
B	210-50-5	1.1	0	0.1	1.4	0.1	0	0	0	0	0	0	0	0	2.7
	210-40-10	0.5	0	0	0.8	0	0	0	0	0	0	0.2	0	0.1	1.6
	140-50-5	2.2	0.1	0	0.8	1.2	0.3	0	0	0	0	0	0	0.1	4.7
	140-40-10	1.8	0	0	0	0.8	0	.6	0	0	0	0	0	0	3.2
	140-40-5	3.8	0	0.2	0.1	1.1	0.8	0	0	0	0	0.1	0	0	6.1
	210-50-10	1.4	0	0	0.2	0	0.2	0	0	0	0.1	0.1	0	0	2.0
	210-40-5	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0.6
	140-50-10	0.9	0.3	0	0.1	0.3	0	0	0.1	0	0	0.4	0	0	2.1

*A: regeneration group; B: established group.

Table 6. Mean total numbers of seedlings (all classes)

a) Interaction table

Cutting cycle (years)	Maximum diameter (cm)	Residual 210 m³/ha	Volume 140 m³/ha
		no. seedlings /ha	
5	50 cm	148 200	165 800
	40 cm	78 000	155 200
10	50 cm	157 600	50 200
	40 cm	143 800	196 000

b) Analysis of variance

Source of variation	Degree of freedom	F	Significance
Main effect			
Residual volume (B)	1	0.002	N.S.
Cutting cycle (C)	1	0.028	N.S.
Maximum diameter (D)	1	0.464	N.S.
First order of interations			
B X C	1	1.601	N.S.
B X D	1	4.400	S*
C X D	1	5.036	S*
Second order interactions			
B X C X D	1	0.779	N.S.
	7		
Error	56		
	63		

*Significant at P = .10

$F_{.10}[1,56] = 2.8$

had any significant effect on seedling numbers, interactions of residual volume-maximum diameter and of cutting cycle-maximum diameter did have an effect.

The interaction residual volume-maximum diameter showed that numbers of seedlings increased with residual volume of 140 m^3/ha when the maximum diameter is 40 rather than 50 cm, and with a residual volume of 210 m^3/ha when the maximum diameter is 50 rather than 40 cm. The interaction cutting cycle-maximum diameter showed that numbers of seedlings increased with a maximum diameter of 40 cm when the cutting cycle is 10 rather than 5 years and with a maximum diameter of 50 cm when the cutting cycle is 5 rather than 10 years.

The results suggest that, in order to obtain a maximum number of seedlings under the experimental conditions, it is preferable to use the following combinations of treatments: 140-40-10 or 210-50-10. More seedlings are produced with the first combination.

Established group

The interaction table of total numbers of seedling for the established class is shown in Table 7. For this group, residual volume and cutting cycle each have a significant effect on seedling numbers. However, these effects are less meaningful because the treatments are involved in interactions: both the interactions, residual volume-cutting cycle and residual volume-maximum diameter, are significant.

The residual volume-cutting cycle interaction suggests that more seedlings are produced with both cutting cycles when the residual volume is 140 m^3/ha rather than 210 m^3/ha. The interaction residual volume-maximum diameter suggests that more seedlings are produced with both maximum diameter when residual volume is 140 m^3/ha rather than 210 m^3/ha. However, a maximum number of seedlings is obtained in the established group with the 140-40-5. A direct effect of the lower residual volume is a more open stand. The increased solar radiation reaching the forest floor is thought to account for the higher survival of seedlings with this treatment. The 5-year cutting cycle appears to promote seedling density by perpetuating more open conditions. However, this combination is different from that found best for the regeneration group. It is preferable, therefore, to use the combination that is best for the established group, although fewer seedlings would result in the regeneration class (Table 6).

Treatment effects on regeneration

Distribution of seedlings in the established group over a compartment was assessed by counting the numbers of 16 m^2 plots containing at least one seedling of any species of the established class. The degree of stocking of a compartment depends on the percentage of its sample plots that are stocked (Table 8). They vary considerably. Compartments in which 100% was obtained (140-50-5, 140-40-10, 140-40-5, 140-50-10) have residual volumes of 140 m^3/ha, the same as was found best for a maximum number of seedlings in the established group.

The estimation of distribution of regeneration in the established group is rather crude; therefore, a satisfactory level of stocking should be at

Table 7. Mean total numbers established seedlings

a) Interaction table.

Cutting cycle (years)	Maximum diameter (cm)	Residual 210 m³/ha	Volume 140 m³/ha
		no. seedlings /ha	
5	50 cm	2 700	4 700
	40 cm	600	6 100
	50 cm	2 000	2 100
	40 cm	1 600	3 200

b) Analysis of variance

Source of variation	Degree of freedom	F	Significance
Main effects			
Residual volume (B)	1	20.420	S*
Cutting cycle (C)	1	3.000	S*
Maximum diameter (D)	1	0.453	N.S.
First order of interactions			
B X C	1	5.697	S*
B X D	1	3.182	S*
C X D	1	2.306	N.S.
Second order interactions			
B X C X D	1	0.243	N.S.
	7		
Error	56		
	63		

*Significant at ^{D} = .10

$F_{.10}[1,56] = 2.8$

Table 8. Regeneration stocking for established seedlings, by compartment

Cutting cycle (years)	Maximum diameter (cm)	Residual 210 m³/ha		Volume 140 m³/ha	
		Compt.	%	Compt.	%
5	50 cm	1	75.0	3	100.0
	40 cm	7	50.0	5	100.0
	50 cm	6	62.5	8	100.0
	40 cm	2	87.5	4	100.0

least 75%. This implies that at least six of eight plots of each compartment contain seedlings. Two compartments have less than 75% of stocking.

Seedling numbers by species and size class

Table 4 shows the number of seedlings per hectare for each class, compartment, and species.

Sugar maple

Sugar maple is consistently the species with the highest number of seedlings. It is represented by the first five classes in every compartment. Class 6 is lacking only treatment combination 210-40-10.

For Classes 0 to 2 sugar maple is the species with the highest number of seedlings, and in Class 3, it ranks second. From Classes 0 to 6 we can observe a gradual decrease in the number of seedlings. These results show a trend observed by other authors: regeneration of sugar maple is easily achieved with partial cutting (Bray 1956, Fowells 1965, Kelty and Nyland 1981, Metzger and Tubbs 1971, Tubbs and Metzger 1969).

Beech

High numbers of beech seedlings occurred in Classes 0, 1, 2, and 3. For Classes 4 to 6, their occurrence is sparse. Considering the high numbers of seedlings in the first four classes, it becomes apparent that this species is not difficult to regenerate on this site. According to Fowells (1965), beech seedlings prefer protected small openings for their development. In this type of community, sugar maple is usually the most abundant species and beech the second most abundant.

Basswood

Basswood regeneration shows the same type of occurrence as beech, but generally fewer numbers.

Yellow birch

Seedlings of yellow birch occurred as Classes 0 and 1 in only three compartments (Table 4). Regeneration in other classes took place in only one compartment with each class (except for Class 6). Compared to sugar maple and beech, the regeneration of yellow birch is poor. Research on regeneration of this species indicates it needs a good light regime to reproduce well in the understorey (Godman and Krefting 1960, Hatcher 1966, Jarvis 1957, Linteau 1948, Winget 1968, Winget and Kozlowski 1965). In addition, these authors, together with Barret et al. (1962), Burton (1956), Roberge (1977), Tubbs and Metzger (1969) and Zillgitt and Eyre (1945) specify that soil scarification is also important to yellow birch establishment. In our case, selection cutting increased available light, and the logging operations effected partial soil scarification. The rarity of overstorey yellow birch and seedlings suggests the disturbance accompanying single-tree selection was not sufficient to promote regeneration of this species. Possibly soil scarification alone was inadequate for yellow birch regeneration, because logging operations, which were not used primarily to scarify the soil, were likely limited on skid trails.

Other species

Red maple, black ash, white ash, ironwood, and balsam fir occurred in Class 0 of almost all compartments (Table 4). From Class 0 to Class 6 their densities decrease drastically and their presence becomes more infrequent. A high mortality rate in subsequent years seems to characterize those species, compared to sugar maple. The different treatments did not seem to have different effects on seedling establishment of red maple. The regeneration of red oak, white pine, white spruce, white elm, and hemlock was poor. These species were also rare in the overstorey.

According to Fowells (1965), most of these species are difficult to regenerate. Red maple can have a good germination rate, but survival may be very low on less favorable seedbeds. White ash requires particular conditions: full sunlight, high soil moisture, and fertility. Moisture can be a critical factor for red oak, white spruce, and eastern hemlock. Furthermore, the seeds of eastern hemlock have very low germination rates. White pine seedlings need light after establishment for good survival. Generally, the selection method is unfavourable to the demands of these species.

SUMMARY AND CONCLUSIONS

- A regeneration survey was made in a tolerant hardwood stand at the Petawawa National Forestry Institute. Sampling was made in rectangles of 16 m^2 for established seedlings (measuring more than 1.25 m in height), whereas seedlings measuring less than 1.25 m in height were sampled in three subdivisions of 1 m^2 randomly located within the subplots. There were eight compartments subjected to three treatments each at two levels: (1) residual volume (140 and 210 m^3/ha), maximum diameter (40 and 50 cm), and cutting cycle (5 and 10 years).

- No single treatment significantly influenced the abundance of small seedlings (the regeneration group), but significant interactions produced effects. The interactions of residual volume-maximum diameter and of cutting cycle-maximum diameter showed that it is preferable to use the following combinations to obtain a maximum number of seedlings: 140-40-10 or 210-50-5. However, slightly more seedlings are produced with the first combination.

- For larger seedlings 1.25 to 3.75 cm tall (the established group), the treatments residual volume and cutting cycle had significant effects but, as they are interactive, their single effect was less meaningful. The interaction's residual volume-cutting cycle and residual volume-maximum diameter imply that a maximum number of seedlings will be obtained with the combination 140-50-5.

- Only residual volume had a real effect on area distribution. Furthermore, 100% of stocking was obtained only in compartments which were reduced to the level of 140 m^3/ha.

- Sugar maple seedlings are the most abundant, and are present in almost all compartments. Beech is the second most abundant species. Other species occur less frequently.

- The number and distribution of established seedlings is considered adequate to sustain the selection system throughout the range of treatments under study. Apart from sugar maple, beech, basswood, and yellow birch, most species do not seem well suited to the single-tree selection method.

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